

Prudential Regulation and Bank Accounting*

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Abstract

This study focuses on how to design a mechanism to coordinate prudential regulation with bank accounting. I study a setting in which a bank chooses loan quality and makes asset substitution decisions. The social planner sets regulatory leverages and the accounting regime (either fair value accounting or historical cost accounting) for banks to report on loan performance. By the standard of ex ante bank value, I find that the historical cost regime dominates the fair value regime for medium values of asset substitution risk and asset substitution constraint, for low values of asset specificity, fundamental risk of loans and marginal cost of loan quality, and for high values of marginal benefit of loan quality and the liquidity benefit of bank debtholders. For other values of these parameters, fair value accounting dominates. This study contributes to the theoretical debate on bank opacity by incorporating *both the asset side and the liability side* of the balance sheet in designing a mechanism to coordinate prudential regulation with bank accounting. The paper makes important policy implications such as cycle-contingent regulations, asset risk class-contingent regulations and country-contingent accounting standards.

Keywords: regulatory leverage; historical cost accounting; fair value accounting; regulatory coordination; cycle-contingent regulation; debt overhang; asset substitution.

1 INTRODUCTION

A discussion is under way on alternative accounting standards for banks, especially financial reporting opacity, in the context of prudential regulation of banks (Laux and Leuz 2009). Prudential regulations are reformed constantly: witness Basel I\Basel II\Basel III or the mandatory stress test under Dodd-Frank Act. The 2007-2009 financial crisis spawned vigorous debates on the role of regulations (Admati and Hellwig 2013, Gale 2010). Prudential regulation is accounting-based with prudential leverage ratios as the ratio of the bank’s liabilities to assets. Therefore, coordination of prudential regulation and bank accounting is necessary to enhance social welfare.

Some stress the importance of the *asset* side of bank balance sheets. For example, Morgan (2002, p. 874) states that “the opacity of banks exposes the entire financial system to bank runs, contagion, and other strains of systemic risk. Take away opacity and the whole story unravels.” Similarly, Nier and Bauman (2006, p. 337) believe that “a bank that discloses its risk profile exposes itself to market discipline and will therefore be penalized by investors for choosing higher risk.” These views thus argue for *fair value* accounting with its timely reports on interim performance of loan portfolios, thereby enabling regulators to fine-tune the target leverages to precisely control the bank’s asset substitution decisions. That is, fair value accounting makes it feasible for the regulator to discipline bank’s excessive risk taking, which may eventually result in systemic risk.

Others emphasize the *liability* side, pointing to the role of banks in creating highly liquid, money-like debt claims (e.g., demand deposits and the associated banking services). Such claims are collateralized to make them information-insensitive. To further make it, they argue, banks should be “secret keepers,” so governmental guarantees, regulation and supervision should not force banks to disclose information (Dang et al. 2014; Holmstöm 2015). These views accordingly support *historical cost* accounting, which does not report the interim performance of bank’s loan portfolios

on a timely basis, and so does not trigger interim insolvency risk and therefore safeguards debtholders' deposits and enhances their liquidity benefit, which is defined as the convenience spread in the finance literature.¹

I incorporate both the asset and the liability side of bank balance sheets to investigate how the social planner coordinates prudential regulations with bank accounting to enhance ex ante bank value (the sum of ex ante debt value and equity value). How should the optimal regulatory leverage be set for a given accounting regime (fair value accounting or historical cost accounting)? Under what conditions will one regime dominate the other? I address these questions in a setting in which a representative bank chooses its loan quality and makes its asset substitution decision, and a social planner sets prudential leverage targets to maximize ex ante bank value, which captures depositor's liquidity benefit as well because investors take liquidity benefit into consideration when pricing on debts.

Banks are plagued by debt overhang, posing problems of both asset substitution and underinvestment in loan quality. A bank may increase the risk of its loan portfolio to gamble on the upside potential at the expense of the debtholders, and expected value of loan portfolio can suffer as a result. For example, it may undertake projects with negative net present value (Jensen and Meckling 1976; Dewatripont and Tirole 1993; Gron and Winton 2001; Admati and Hellwig 2013), construct derivatives for speculation based on the loan portfolio, or reduce the frequency of filed inspections at borrowers' facility in hopes of achieving the upside potential. Banks with excessive leverage may forgo positive net present value projects and thus under-invest in the quality of the loan portfolio (Myers 1977; Admati et al. 2012).

I incorporate these two debt overhang problems in a two-period model characterized by maturity mismatch, a key characteristic of banking as such. The bank finances its long-term lending (its largest asset item) using short-term deposits (its largest li-

¹Subramanian and Yang (2018) document that on average liquidity benefit per deposit dollar is around 25% with a standard error of 0.08 for banks in the U.S. over the period 1991 to 2008.

ability item). Specifically, it chooses the quality of the loan portfolio in period 1 and makes its asset substitution decision in period 2. Asset substitution may enhance the bank's equity value in period 2; Anticipating this, the bank is incentivized to choose a higher quality loan portfolio in period 1. Put another way, if the bank's period 2 asset substitution is constrained, its period 1 incentive for quality will be dampened (Lu, Sapra, and Subramanian 2019).

Apparently, the higher the bank's leverage, the greater incentive to engage in asset substitution. Thus, the social planner may naturally want to lower the regulatory leverage target in period 2 in order to constrain asset substitution. But this reduces the bank's incentives for quality as noted. To counteract this effect, the social planner may lower leverage target in period 1 to reduce debt overhang with respect to loan quality. In this case, the leverage targets in both periods are lowered and the bank's debt capacity is accordingly reduced, which implies less liquidity benefit for the debtholders (Bryant 1980; Diamond and Dybvig 1983; Calomiris and Kahn 1991; Gale 2010).

The model captures such economic tradeoffs, and more importantly, it also introduces an accounting tradeoff (fair value vs. historical cost). Under fair value accounting, in which interim loan performance is reported, the social planner can tie the interim prudential leverage to the fair value report and so precisely manage bank's asset substitution (Giammarino, Lewis, and Sappington 1993; Kahn and Winton 2004; Allen, Carletti, and Marquez 2011; Bulow, Goldfield, and Klemperer 2013). However, the interim fair value report brings an interim volatility into the market value of the bank's debt and equity, entailing an interim insolvency risk. Under historical cost accounting in which the loan performance is not reported on a timely basis, the social planner cannot precisely manage asset substitution. However, at the same time, the absence of timely fair value reports eliminates interim volatility in the

market value of debt and equity, suppressing the interim insolvency risk.²

The main elements in the model are (1) bank asset substitution and quality of loan portfolio (the asset side of the bank balance sheet), (2) the bank debtholders' liquidity benefits (the liability side), (3) the regulatory leverage target (prudential regulation), and (4) historical cost accounting or fair value accounting (bank accounting).

Bank value is defined as the sum of debt plus equity value, so both assets and liabilities are important for the bank's value. Therefore, my main results relate to the conditions under which one accounting regime dominates the other in terms of bank assets and liabilities parameters, using the ex ante bank value as the criterion. The assets related parameters are: asset substitution risk, which captures the upside potential for banks to choose asset substitution; asset substitution constraint, which captures the cost of asset substitution for banks; the asset specificity, which captures the social loss in bankruptcy; fundamental risk of loan portfolio, which captures the volatility of loan; marginal benefits of loan quality; marginal cost of loan quality; The liability related parameter is liquidity benefit, which captures the non-pecuniary benefits to depositors and will be priced into debt value.

Given the economic tradeoffs and accounting tradeoffs described above, I find that historical cost accounting dominates fair value accounting for the following parameter values of bank assets: medium values of asset substitution risk; medium values of asset substitution constraint; low values of asset specificity; high values of marginal benefit or low values of marginal cost of loan quality; low values of fundamental risk of the loan portfolio. Historical cost also dominates fair value for the liabilities parameter: high values of the liquidity benefits of bank debtholders. For other parameter values, fair value dominates historical cost.

²This paper studies two pure forms of accounting regime for bank loans representing the major bank's assets, fair value accounting and historical cost accounting. The fair value of a bank loan is level 3 fair value, determined by the bank's private information. Therefore, under historical cost accounting, as private information about loans is not incorporated into loan interim fair value, the accounting report on bank loans is less informative than that under fair value accounting. Because I study accounting standard setting, I do not consider any managerial discretion in this model.

My investigation contributes to the *public policy* debate on *prudential regulation and bank accounting*.

(1) The social planner may condition regulatory leverages and accounting choice on the asset substitution *risk classes of bank loans* and/or the *strength of bank's corporate governance*. For bank loans with extremely low or extremely high asset substitution risk, fair value accounting is preferable, because fair value accounting makes it feasible for social planners to precisely curb extremely low or allow extremely high asset substitution risk by setting high regulatory leverages, which may enhance liquidity benefits and bank value as results; and for those with mid-level risk, historical cost accounting is better, because the low leverage to precisely curb or allow asset substitution will damage liquidity benefits, while loan quality is suppressed or not incentivized to the high extent due to the medium asset substitution incentives. To the extent that the asset substitution risk varies over the phases of business and credit cycles, my result suggests *cycle-contingent regulation*, if practical. Specifically, insofar as the asset substitution risk is high at peak, low in trough and medium in contraction or expansion, it is optimal to apply fair value accounting at cyclical peaks and troughs and historical cost accounting during the upswings and downswings. The results also suggest *corporate governance contingent regulation*, if practical. Specifically, to the extent that the asset substitution constraint is severe for banks with good or bad corporate governance and less severe for those with mid-quality corporate governance, it is optimal to apply fair value accounting for the former and historical cost accounting for the latter.

(2) Fair value accounting is optimal for bank assets with high specificity or high illiquidity, because the high social loss due to high specificity or high illiquidity may make the fine-tuning leverage to precisely manage bank's asset substitution to enhance bank value less attractive under fair value accounting, which may also bring interim insolvency to damage bank value; Historical cost accounting is for generic or liquid

assets. Plantin, Sapra, and Shin (2008) generate an opposite result in a setting of premature asset sales triggered by higher-order beliefs. Accordingly, I identify another rationale relating to the desirability of either historical cost accounting or fair value accounting in terms of specificity of bank assets.

(3) One of my results sheds light on impairment accounting (or lower-of-cost-or-market rule). To the extent that the marginal benefit (cost) of loan quality is high (low) in good times and the opposite in bad times, it is socially optimal to mandate historical cost accounting in good times and fair value accounting in bad times. This is what impairment accounting prescribes. Therefore, I add the benefit of impairment accounting to the existing literature by exploring the way in which impairment accounting is beneficial to lenders (banks), while the existing literature (Göx and Wagenhofer 2009; Li 2017) identifies the benefits of impairment accounting to borrowers.

(4) Another result relates to liquidity benefits to bank depositors. To the extent that depositors in *developing countries* value liquidity benefits relatively more than those in developed countries, my result implies that *historical cost accounting* is better for developing countries and *fair value accounting* is better for developed countries. This should warn developing countries against their rush to adapt their local accounting standards to the International Financial Reporting Standards, which are moving rapidly towards fair value accounting.

Overall, my study identifies the characteristics of bank assets and liabilities to take into account in designing prudential regulation and bank accounting. I also provide specific examples of how the two regulations should be optimally coordinated.

The study contributes to the theoretical literature on bank accounting. (1) It incorporates *both the asset side and the liability side* of bank's balance sheets in the discussion on bank opacity. (2) It focuses on regulatory coordination: How are *prudential regulation and bank accounting* optimally coordinated?

Li (2017) and Bertomeu, Mahieux, and Sapra (2018) also study the coordination of prudential regulation and bank accounting but with a different focus. Li (2017) introduces capital issuance decisions whereas Bertomeu, Mahieux, and Sapra (2018) introduce accounting information system design, and both papers study the loan risk decisions. By contrast, I introduce the loan quality decision, which affects both the mean and the variance of loan fundamentals.

Several papers have examined prudential regulation under fair value accounting only, ignoring historical cost accounting. Heaton, Lucas, and McDonald (2010) investigates the design of capital requirements under mark-to-market. Lu, Sapra, and Subramanian (2019) study a setting in which the bank can misreport its performance under fair value accounting. The present paper, instead, extends and modifies their model, studying historical cost accounting as well, and thus provides a fuller picture of the optimal accounting choices for banks under different conditions.

Most previous accounting studies do not endogenize prudential regulation. Allen and Carletti (2008) focuses on historical cost versus fair value accounting as well but they are interested in contagion from the insurance sector to the banking sector. Plantin, Sapra, and Shin (2008) also considers historical cost versus fair value accounting for banks, focusing on bank's asset sales decisions. Burkhardt and Strausz (2009) analyze historical cost versus impairment accounting on asset substitution. I factor in the bank's quality decision as well as the asset substitution decision, allowing for the tradeoff between them. Corona, Nan, and Zhang (2018) examine historical cost versus fair value accounting for assets in place, focusing on bank's lending decisions as opposed to asset substitution and quality decisions, which are the key ingredients of the present study. In addition, they investigate the bank's voluntary choice of accounting regimes whereas in my model the regime is mandatory. Finally, Bleck and Gao (2018) compare the two accounting regimes and study the loan selling decision

assuming the prudential regulation (capital requirement) is exogenous.³

My paper offers some empirical predictions. For example, it indicates where the cycle-contingent or asset risk-class contingent regulations, corporate governance-contingent regulations, asset specificity-contingent accounting methods, loan quality-contingent accounting methods or country contingent accounting methods are more suitable. By developing proper proxies for the parameters in my model, future empirical research can test my theoretical results.

Section 2 describes the model setup, sections 3 and 4 analyze the historical cost regime and the fair value regime, and section 5 compares the two. The proofs of the Propositions are given in the Appendix. Section 6 summarizes and discusses potential research extensions.

³Some papers focus on attributes of accounting other than historical cost versus fair value accounting. For example, Corona, Nan, and Zhang (2015) focus on accounting quality.

2 THE MODEL

I model a setting in which (i) a representative bank chooses the quality (q) of its loan portfolio in period 1 and makes its asset substitution decision (a) in period 2; (ii) a social planner chooses regulatory leverage targets (equivalently, capital requirements) for period 1 (L_1) and period 2 (L_2)⁴ and an accounting regime (fair value accounting or historical cost accounting). This is a modified extended model in Lu, Sapra, and Subramanian (2019).

2.1 The Loan Portfolio

At date 0, the bank originates a loan portfolio whose terminal cash flow V will be realized at date 2, $V = XZ$. Two decisions by the bank affect V : a date 0 quality decision $q \in \{q_H, q_L\}$ which affects X , and a date 1 asset substitution decision $a \in \{0, 1\}$, which affects Z .

At date 0, the bank can engage in costly loan screening to filter loan applications. The cost of quality is $C(q)$ where $C(q) = c$ if $q = q_H$ and $C(q) = 0$ if $q = q_L$. The higher quality, q_H , generates better interim loan performance X and thus greater net present value. Specifically, $X \sim \text{Lognormal}(q, \sigma_X^2)$ with density $g(X)$ and cumulative distribution function $G(X)$. Equivalently, $X = e^{q + \sigma_X \varepsilon}$ where $\varepsilon \sim N(0, 1)$. σ_X captures the fundamental risk of the loan portfolio, i.e. the volatility of the loan fundamental. For example, financing a firm's R&D project is riskier than loans for other projects. I assume $(e^{q_H} - e^{q_L})e^{\frac{1}{2}\sigma_X^2} > c$, which implies that the marginal benefit of the higher quality q_H relative to q_L exceeds the marginal cost, so the first-best loan quality is q_H to maximize the expected net return from loan quality screening. Naturally, the higher quality q_H increases both the mean and the variance of X , capturing

⁴This is not a dynamic model to deal with multiple-period leverage, but instead, proposes a leverage bundle as the socially optimal choice. The two leverages in my model represent the prices for deposits in two periods. Practically, regulators do in fact apply different capital requirements under different economic conditions when needed, for example in recession.

the idea that higher expected return comes with higher volatility.

At date 1, after privately learning the realized value of the interim loan performance X , the bank can engage in asset substitution, as by reducing the frequency of inspections at borrower's facilities or increasing the riskiness of the loan portfolio using derivatives. Specifically, $Z \sim \text{Lognormal}(-ak, a^2\sigma_Z^2)$ with density $f(Z)$ and cumulative distribution function $F(Z)$. Equivalently, $Z = e^{a(\sigma_Z\eta - k)}$ where $\eta \sim N(0, 1)$. σ_Z captures the asset substitution risk, i.e, the attractiveness of the asset substitution or the opportunity of asset substitution for banks. For example, in cyclical peaks, the availability of derivatives for speculation is greater than in troughs, hence σ_Z is relatively higher in peaks. k captures the constraint on asset substitution: the frequency of stress testing, say, or the relative soundness of corporate governance. I assume $k > \frac{1}{2}\sigma_Z^2$, which implies that asset substitution is very costly. Naturally, asset substitution decreases the mean of Z and increases its variance and skewness, implying that on average asset substitution is value-destroying.

2.2 Prudential Regulation and Bank Accounting

Banking industry has one essential characteristic feature, namely maturity mismatching. That is, banks normally issue short-term deposit liabilities to finance long-term loan assets. On the asset side of the balance sheet, because banks are highly leveraged, they are plagued with asset substitution and underinvestment in loan quality. Specifically, because of high leverage, banks have an incentive to use depositors' money to gamble on the upside potential, aggravating the asset substitution problem, which may damage loan NPV. In addition, the bulk of potential profits from loan origination will accrue to depositors, but the cost of loan screening is borne by shareholders. Therefore, banks are discouraged from engaging in costly loan quality investment, again to the detriment of loan NPV. On the liability side, banks' role of providing

liquidity to depositors is crucial to social welfare. The higher leverage, the more deposits will be issued, and the greater the liquidity benefits will be. Hence, bank insolvency risk jeopardizes liquidity benefits, hence deposits.⁵ Due to their lack of bargaining power, individual depositors cannot contract directly with banks to discipline the latter's risk taking, which bears on insolvency risk. The regulator steps in to represent individual depositors and discipline risk taking, and banking is accordingly characterized by strict regulation, such as capital requirements and stress testing. Because neither asset substitution nor quality choice is verifiable, the present model focuses on the leverage ratio, which is invoked by prudential regulation and is well identified in the literature as the root of the problem of asset substitution and loan quality incentives.

Because the bank chooses its loan quality in period 1 and makes its asset substitution decision in period 2, the social planner ideally sets a prudential leverage level bundle for each period, $\{L_1, L_2\}$. Moreover, given maturity mismatching, the volume of the deposits (or the deposits' price) may differ between period 1 and 2.⁶ This further enhances the desirability of time-varying leverage ratios as opposed to fixed.

Because prudential leverage ratios are based on bank balance-sheet data, bank accounting plays a critical role in regulations. The debate on historical cost accounting versus fair value accounting is a case in point. Specifically, at date 1, fair value accounting mandates interim loan performance reports; That is, disclosure of the bank's private information on the realized value of X .⁷ Thus, the social planner can tie period 2 prudential leverage L_2 to the accounting report X . Historical cost accounting

⁵The Federal Deposit Insurance Corporation guarantees only a portion of deposits. My setup is relevant as long as the depositors' loss exceeds this limit, which is especially acute in financial crises in which systemic risk threatens the whole banking sector.

⁶My assumption of short-term deposits serves purely to highlight the maturity mismatch between assets and liabilities. All my results hold with a mixture of long-term and short-term deposits.

⁷Because of the long-term nature of loans, realized value of X at date 1 is the bank's private information, and not cash flow. The cash flow is not X but $V = XZ$, which will be realized at date 2. In addition, because the realized value of X is hidden information, the fair value report of X is a Level 3 input in the fair value hierarchy.

by contrast, does not mandate a report of X at date 1, so the prudential leverage level for period 2 cannot be tied to interim performance. In short, fair value accounting provides more information than historical cost accounting.⁸ However, owing to the multiple frictions in the economy, the interactions of asset substitution, underinvestment, and liquidity benefit provisions, “the more, the merrier” is not always apt as shown in later sections.⁹

2.3 Timeline

Given the social planner’s choices of prudential regulation $\{L_1, L_2\}$ and bank accounting (historical cost or fair value), the game plays out as follows:

Date 0:

- (i) The bank finances the initial investment I via short term debt, D_0 , and equity, E_0 . The debt matures at date 1 with maturity value L_1 .
- (ii) The bank chooses the loan quality, $q \in \{q_H, q_L\}$, and incurs quality cost $C(q)$.

Date 1:

- (i) The interim loan performance X is realized and is known privately to the bank. It is disclosed under fair value accounting but not under historical cost accounting.
- (ii) Denote the market values of the bank’s debt and equity at date 1 before L_1 is paid as D_1 and E_1 , respectively. If the bank is insolvent, i.e., $D_1 + E_1 < L_1$, the bank goes bankrupt and the liquidation value of the loan portfolio is normalized to 0 because

⁸The difference between two regimes is that fair value accounting reports interim loan performance on a timely basis while historical cost accounting does not. Both regimes report the loan origination value at date 0 and realized value at date 2.

⁹To focus on quality choice and asset substitution decisions, I take the bank’s scale of lending as given, that is, I assume a fixed amount of investment I in place at the beginning of the game. The literature has investigated the scale of investment thoroughly (e.g., Corona, Nan, and Zhang (2018)). As a consequence, I cannot deal with hybrid accounting regimes in this model. For example, impairment accounting mandates the disclosure of $\min\{I, X\}$ at date 1. To make it interesting enough, my model must endogenize I before addressing the merits and demerits of impairment accounting. However, Proposition 9 in Section 5 does imply the desirability of impairment accounting, which is also summarized in the Introduction.

the pre-mature project is low-valued. If the bank is solvent, i.e., $D_1 + E_1 \geq L_1$, the bank makes the required debt payment L_1 by issuing new debt and (if necessary) equity.¹⁰ The debt issued at date 1 matures at date 2 with maturity value L_2 .

(iii) The bank makes its asset substitution decision $a \in \{0, 1\}$.

Date 2:

(i) The terminal cash flow of the bank's loan portfolio is realized as $V = XZ$.

(ii) If the bank is insolvent, i.e., $V < L_2$, it goes bankrupt and the liquidation value of the loan portfolio is αV where $\alpha \in (0, 1)$; Thus $1 - \alpha$ represents asset specificity, causing deadweight loss in liquidation. If the bank is solvent, i.e., $V \geq L_2$, the bank makes the required debt payment L_2 .¹¹

2.4 Payoffs

At date 0, depositors lend D_0 to the bank, and shareholders receive it and incur the cost of quality investment $C(q)$, so the net proceeds received will be: $D_0 - C(q)$.

Because depositors value the liquidity benefits, their payoffs consist not only of the pecuniary amount (cash flow from the bank) but also a non-pecuniary benefit, the liquidity benefits or convenience spread in finance literature. Hence, at date 1, if the bank is solvent ($D_1 + E_1 \geq L_1$), the depositors' period 1 payoff is $L_1(1 + \lambda)$, where λ represents the liquidity benefit per dollar deposited. In period 2 depositors lend D_1 to the bank. Thus, bank shareholders' payoff is $D_1 - L_1$. If the bank is insolvent, both depositors and shareholders receive nothing.

¹⁰If the amount of new debt exceeds the required payment of the old debt, i.e. if $D_1 > L_1$, the bank is assumed to use the surplus as new equity. For example, the bank may issue restricted stock whose vesting date is date 2. The reason for this assumption is to make things easy. In practice, the bank could pay dividends with the extra money. However, this would decrease equity. Therefore, the equity value at date 1 will have to deduct the dividend paid, which is a constant. Deducting a constant does not change the essence of the story. Therefore, I normalize the dividend paid to 0 for ease of calculation.

¹¹If loans are prematurely liquidated at date 1, their liquidation value is much lower than at maturity (date 2). To capture this difference, I normalize the date 1 liquidate value to 0 and assume a positive liquidation value αV at date 2.

At date 2, if the bank is solvent ($V \geq L_2$), depositors' payoff is $L_2(1 + \lambda)$. Thus, the shareholders' payoff is $V - L_2$. If the bank is insolvent, depositors' payoff is $\alpha V(1 + \lambda)$ ¹² and shareholders receive nothing. I assume that $\alpha(1 + \lambda) < 1$ to avoid the unrealistic scenario in which liquidation at date 2 generates a greater social value ($\alpha V(1 + \lambda)$) than the cash flow without deadweight loss (V).

2.5 Endogenous and Exogenous Variables

I focus on the bank's loan quality choice $q \in \{q_H, q_L\}$ at date 0 and its asset substitution decision $a \in \{0, 1\}$ at date 1. I assume that the social planner's objective is to maximize bank's value at the date 0, that is, $\pi_0 \equiv D_0 + E_0$, the sum of the date 0 debt value and equity value while the bank's objective is to maximize equity at all dates. Given these objectives, I investigate the social planner's optimal choices of prudential leverage for periods 1 and 2, $\{L_1, L_2\}$, under a given accounting regime, either historical cost accounting or fair value accounting, to induce the bank's decision on loan quality and asset substitution. I will identify the conditions under which one accounting regime dominates the other. Eventually, I will show how to design the optimal mechanisms for coordinating prudential regulation with bank accounting to enhance bank value.

In my model, several parameters in economic environments will shed light on the optimal coordination of prudential regulation and bank accounting. On the asset side, I am interested in two sets of parameters in particular:

(i) those that affect the bank's quality decision: σ_X (fundamental risk of the loan portfolio); q_H relative to q_L (the incremental benefit of loan quality); and c (the incremental cost of loan quality).

(ii) those that affect the bank's asset substitution decision: σ_Z (asset substitution

¹²If the bank is insolvent at date 2, the loan portfolio assets will be forced to go into liquidation procedure. After paying liquidation fee, such as attorneys' fee, the remaining value of loans will be accrued to bank's debtholders, depositors. For every dollar of receipts, depositors value the related liquidity benefit λ . Because of liquidity benefit, one of the components of social value, social planner will have to consider the effect of deadweight loss on optimal regulation.

risk); k (asset substitution constraint); and $1 - \alpha$ (the deadweight loss from date 2 insolvency due to asset specificity).

On the liability side, I am interested in parameter λ (liquidity benefit to depositors).

3 PRUDENTIAL REGULATION UNDER HISTORICAL COST ACCOUNTING

Under historical cost accounting, interim loan performance X is not publicly disclosed at date 1. However, the bank knows X . At date 1, the bank chooses its asset substitution decision to maximize its expected payoff at date 2, given its private knowledge of X :

$$\max_a \mathbb{E} [1_{V \geq L_2} \bullet (V - L_2) | X], \quad (1)$$

where the bank will be solvent when its date 2 bank value V exceeds its date 2 obligation L_2 , and $1_{V \geq L_2}$ is an indicator function equal to 1 if $V \geq L_2$ and 0 otherwise.

The following proposition confirms the conventional wisdom that high leverage leads to asset substitution.

Proposition 1. *(a) At date 1, the bank chooses asset substitution ($a = 1$) over no asset substitution ($a = 0$) if and only if leverage is high enough ($L_2 > \gamma_0 X$).*

(b) At date 1, date 2 insolvency risk is $F\left(\frac{L_2}{X}\right)$.

In the foregoing, γ_0 is defined by

$$1 - \gamma_0 = \int_{\gamma_0}^{\infty} (Z - \gamma_0) f(Z) dZ. \quad (2)$$

At date 1, market values of equity and debt are, respectively,

$$\begin{aligned} E_1 &= \mathbb{E} [1_{V \geq L_2} \bullet (V - L_2)] \\ D_1 &= \mathbb{E} [1_{V \geq L_2} \bullet L_2(1 + \lambda) + 1_{V < L_2} \bullet \alpha V(1 + \lambda)] \end{aligned}, \quad (3)$$

where the debtholders receive the maturity value of debt L_2 plus liquidity benefit λL_2 when the bank is solvent at date 2. When it is insolvent they receive the liquidation

value of loans αV plus liquidity benefit $\lambda \alpha V$.

If the interim loan performance X were publicly known, the capital market would know precisely whether the bank will engage in asset substitution or not: Asset substitution takes place if and only if $X < \frac{L_2}{\gamma_0}$ (Proposition 1(a)). If X were known, the market value of the bank (the sum of equity and debt market values) can be denoted as $XB_0\left(\frac{L_2}{X}\right)$ given no asset substitution and $XB_1\left(\frac{L_2}{X}\right)$ given asset substitution, where

$$\begin{aligned} B_0\left(\frac{L_2}{X}\right) &\equiv 1 + \frac{L_2}{X}\lambda \\ B_1\left(\frac{L_2}{X}\right) &\equiv \int_{\frac{L_2}{X}}^{\infty} \left(Z + \frac{L_2}{X}\lambda\right) f(Z) dZ + \int_0^{\frac{L_2}{X}} \alpha Z(1 + \lambda) f(Z) dZ \end{aligned} \quad (4)$$

However, under historical cost accounting, the interim loan performance X is not disclosed. Therefore, the market must assess the distribution of X , and the date 1 market value of the bank (debt plus equity market values) before the payment of L_1 to the period 1 depositors thus becomes:

$$\pi_1(q, L_2) \equiv \int_{\frac{L_2}{\gamma_0}}^{\infty} XB_0\left(\frac{L_2}{X}\right) g(X; q) dX + \int_0^{\frac{L_2}{\gamma_0}} XB_1\left(\frac{L_2}{X}\right) g(X; q) dX. \quad (5)$$

At date 0, the bank chooses loan quality to maximize its equity value:

$$E_0 \equiv \max_q -C(q) + \mathbb{E} \left[1_{\pi_1(q, L_2) \geq L_1} \bullet (\pi_1 - L_1) \right], \quad (6)$$

where the bank will be solvent when date 1 bank value π_1 exceeds its date 1 obligation L_1 .

Analogously, the date 0 market values of debt is

$$D_0 = \mathbb{E} \left[1_{\pi_1(q, L_2) \geq L_1} \bullet L_1(1 + \lambda) \right], \quad (7)$$

where the debtholders receive the maturity value of debt L_1 plus liquidity benefit λL_1

when the bank is solvent at date 1.

The following proposition confirms the conventional wisdom that debt overhang leads to underinvestment in loan quality.

Proposition 2. *[historical cost accounting] (a) At date 0, the bank chooses the low quality (q_L) if and only if the leverage is high enough ($L_1 > \pi_1(q_H, L_2) - c$).*

(b) The bank will be insolvent at date 1 if and only if $L_1 > \pi_1(q, L_2)$.

Propositions 1 and 2 highlight the frictions plaguing in the banking industry, debt overhang problems (asset substitution and loan quality underinvestment) and insolvency problems due to high leverage.

Friction 1: High prudential leverage in period 2 L_2 produces bank's asset substitution incentives and high insolvency risk. With high L_2 , the bank has an effective call option, that is, it can reap the entire upside potential and ignore downside risk. Thus, the bank has an incentive to use depositors' money to gamble, or engage in asset substitution. This is demonstrated by Proposition 1(a): The bank chooses asset substitution ($a = 1$) over no asset substitution if and only if leverage is high enough ($L_2 > \gamma_0 X$). In addition, while high leverage may generate a large liquidity benefit for depositors, it may also engender high insolvency risk at date 2, which jeopardizes liquidity benefit. If the bank goes bankrupt, the promised cash flow to depositors and the liquidity benefit will be curtailed. This is demonstrated by Proposition 1(b): The insolvency risk at date 2 ($F(\frac{L_2}{X})$) is high with a high leverage L_2 .

Friction 2: High prudential leverage in period 1 L_1 gives the bank an incentive to underinvest in quality and thus generates high insolvency risk. With high L_1 , the bulk of the future benefit from quality investment accrues to debtholders. Thus, the bank is discouraged from a costly quality investment. This is demonstrated by Proposition 2(a): The bank chooses low quality (q_L) over high quality if and only if leverage is high enough ($L_1 > \pi_1(q_H, L_2) - c$). Moreover, while high leverage may generate high

liquidity benefit for depositors, it may also produce high insolvency risk at date 1, jeopardizing the possibility of realizing the liquidity benefit. This is demonstrated by Proposition 2(b): The bank will be insolvent if and only if $L_1 > \pi_1(q, L_2)$.

Given the foregoing trade-offs embedded in the bank's private incentives, a social planner sets $\{L_1, L_2\}$ to maximize the bank value at date 0 $\pi_0 \equiv D_0 + E_0$, the sum of the debt value and equity value, as depicted in proposition 3.

Proposition 3. *[historical cost accounting] The social planner sets the optimal leverages $\{L_1^{HC}, L_2^{HC}\}$ as follows:*

(a) $L_1^{HC} = \pi_1(q_H, L_2^{HC}) - c$ and L_2^{HC} is characterized by

$$\int_{\frac{L_2^{HC}}{\gamma_0}}^{\infty} B'_0\left(\frac{L_2^{HC}}{X}\right) g(X; q_H) dX + \int_0^{\frac{L_2^{HC}}{\gamma_0}} B'_1\left(\frac{L_2^{HC}}{X}\right) g(X; q_H) dX = 0, \quad (8)$$

which induces the equilibrium bank decisions:

(b) $Prob(a^{HC} = 1) = G\left(\frac{L_2^{HC}}{\gamma_0}\right)$;

(c) $q^{HC} = q_H$;

and the equilibrium date 0 bank value:

(d) $\pi_0^{HC} = [\pi_1(q_H, L_2^{HC}) - c](1 + \lambda)$.

The social planner sets the prudential leverage in period 2 L_2 to balance the trade-offs in Friction 1 above. High period 2 leverage directly generates higher liquidity benefit, but also increases date 2 insolvency risk, thereby jeopardizing the possibility of realizing the liquidity benefit. In addition, higher leverage induces higher probability of asset substitution, decreasing bank value at date 1. The balance between these forces yields the optimal choice of L_2 (equation (8)), which in turn determines the asset substitution target set by the social planner ($Prob(a^{HC} = 1) = G\left(\frac{L_2^{HC}}{\gamma_0}\right)$).

The social planner also sets period 1 prudential leverage L_1 to balance the trade-

offs described in Friction 2 above. High period 1 leverage directly generates higher liquidity benefit, but also increases insolvency risk at date 1, jeopardizing the possibility of realizing the liquidity benefit. In addition, higher leverage discourages the bank from choosing high quality. The balance between these forces yields the optimal choice of L_1 , which in turn induces the bank to choose high quality ($q^{HC} = q_H$).

Because the social planner sets the prudential regulation leverage bundle $\{L_1, L_2\}$ for the two periods at the same time at date 0, they are naturally optimally combined. Specifically, the social planner sets L_2 to maximize the bank value at date 1 π_1 before the payment of L_1 to period 1 depositors. Because higher bank value at date 1 encourages quality investment, debt overhang problem in period 1 is mitigated, and the social planner can increase L_1 to enhance liquidity benefit in period 1 to the fullest extent, constrained only by the requirement that no interim insolvency is triggered.¹³

¹³Under historical cost accounting, X is not disclosed, so the social planner cannot precisely induce the socially desirable choice of asset substitution, but rather an optimal incidence of asset substitution. In this regard, regulation is less efficient than second-best regulation under fair value accounting. With this less efficient regulation on asset substitution, a social planner has to make sure that high quality is first induced to enhance ex-ante bank value. This is why high quality is always induced under historical cost accounting.

4 PRUDENTIAL REGULATION UNDER FAIR VALUE ACCOUNTING

The bank's asset substitution decision at date 1 is based on its knowledge of the interim loan performance X and the prevailing prudential leverage for period 2 L_2 . Therefore, the bank will engage in asset substitution at date 1 if and only if $\frac{L_2}{X} > \gamma_0$, as in Proposition 1.

Under fair value accounting, X is disclosed at date 1, so the social planner can tie L_2 to X and set $\frac{L_2}{X} = \gamma$ so as to induce no asset substitution ($a = 0$) by setting $\gamma \leq \gamma_0$ or asset substitution ($a = 1$) by setting $\gamma > \gamma_0$. Then, the market value of the bank at date 1 is $\pi_1 = XB_a(\gamma)$ where $\pi_1 = XB_0(\gamma)$ with no asset substitution ($a = 0$) and $\pi_1 = XB_1(\gamma)$ with asset substitution ($a = 1$). Note that because the interim loan performance X is disclosed at date 1, the market value of the bank at this date is different from its counterpart (5) under historical cost accounting, which integrates over the possible values of X .

At date 1, the bank will be solvent if and only if its date 1 value π_1 exceeds its date 1 obligation L_1 , or equivalently, $X \geq \frac{L_1}{B_a(\gamma)}$. At date 0, the bank chooses quality q to maximize its expected equity value at date 0:

$$E_0 \equiv \max_q -C(q) + \int_{\frac{L_1}{B_a(\gamma)}}^{\infty} [XB_a(\gamma) - L_1] g(X; q) dX, \quad (9)$$

and the date 0 debt value is

$$D_0 = \int_{\frac{L_1}{B_a(\gamma)}}^{\infty} L_1(1 + \lambda) g(X; q) dX, \quad (10)$$

where the debtholders receive the maturity value of debt L_1 plus liquidity benefit λL_1 when the bank is solvent at date 1. The following proposition 4 describes the decision rule for the loan quality under fair value accounting.

Proposition 4. *[fair value accounting] (a) At date 0, the bank chooses low quality (q_L) if and only if leverage is high enough ($L_1 > \bar{L}_1(\gamma)$).*

(b) At date 0, the date 1 insolvency risk is $G\left(\frac{L_1}{B_a(\gamma)}\right)$.

In the foregoing, $\bar{L}_1(\gamma)$ is characterized by

$$\int_{\frac{\bar{L}_1(\gamma)}{B_a(\gamma)}}^{\infty} \left[X - \frac{\bar{L}_1(\gamma)}{B_a(\gamma)} \right] g(X; q_H) dX - \int_{\frac{\bar{L}_1(\gamma)}{B_a(\gamma)}}^{\infty} \left[X - \frac{\bar{L}_1(\gamma)}{B_a(\gamma)} \right] g(X; q_L) dX = \frac{c}{B_a(\gamma)}. \quad (11)$$

Proposition 4, along with Proposition 1, highlights the frictions plaguing in my model, namely debt overhang problems (asset substitution and underinvestment in loan quality) and insolvency problems due to high leverage. The first two frictions are similar to Friction 1 and Friction 2 under historical cost accounting, but the third is unique to the fair value accounting regime.

Friction 3: Eliminating asset substitution may decrease the bank's incentive to choose high quality. Specifically, when asset substitution yields a higher interim (date 1) bank value under some conditions, then eliminating it will decrease equityholders' date 0 expected future payoff, undermining the incentive to choose high quality. This friction was first identified in Lu, Sapra, and Subramanian (2019). It represents the interaction between asset substitution and loan quality and may accordingly affect social planner's mechanism design.

Given the above trade-offs embedded in the bank's private incentives, a social planner sets $\{L_1, L_2\}$ to maximize bank value at date 0 $\pi_0 \equiv D_0 + E_0$, the sum of debt value and equity value. Proposition 5 describes social planner's optimal choice of leverages to induce the socially desirable bank's decisions on asset substitution and loan quality.

Proposition 5. *[fair value accounting] The social planner sets the optimal leverages $\{L_1^{FV}, L_2^{FV}\}$ as follows:*

(i) If

$$A\left(\frac{\bar{L}_1(\gamma_a)}{B_a(\gamma_a)}, q_H\right) - A(e^{q_L+S}, q_L) \geq \frac{c}{B_a(\gamma_a)}, \quad (12)$$

$L_1^{FV} = \bar{L}_1(\gamma_a)$ and $L_2^{FV} = \gamma_0 X$ if $B_0(\gamma_0) \geq B_1(\gamma_1)$ and $L_2^{FV} = \gamma_1 X$ if $B_1(\gamma_1) > B_0(\gamma_0)$,

which induces the equilibrium bank decisions:

$$q^{FV} = q_H;$$

$$a^{FV} = 0 \text{ if } B_0(\gamma_0) \geq B_1(\gamma_1) \text{ and } a^{FV} = 1 \text{ if } B_1(\gamma_1) > B_0(\gamma_0);$$

$$\text{the equilibrium date 0 bank value } \pi_0^{FV} = B_a(\gamma_a) A\left(\frac{\bar{L}_1(\gamma_a)}{B_a(\gamma_a)}, q_H\right) - c.$$

$$(ii) \text{ If } A\left(\frac{\bar{L}_1(\gamma_a)}{B_a(\gamma_a)}, q_H\right) - A(e^{q_L+S}, q_L) < \frac{c}{B_a(\gamma_a)},$$

$L_1^{FV} = e^{q_L+S} B_a(\gamma_a)$ and $L_2^{FV} = \gamma_0 X$ if $B_0(\gamma_0) \geq B_1(\gamma_1)$ and $L_2^{FV} = \gamma_1 X$ if $B_1(\gamma_1) > B_0(\gamma_0)$,

which induces the equilibrium bank decisions:

$$q^{FV} = q_L;$$

$$a^{FV} = 0 \text{ if } B_0(\gamma_0) \geq B_1(\gamma_1) \text{ and } a^{FV} = 1 \text{ if } B_1(\gamma_1) > B_0(\gamma_0);$$

$$\text{the equilibrium date 0 bank value } \pi_0^{FV} = B_a(\gamma_a) A(e^{q_L+S}, q_L).$$

$$\text{In the above, } A\left(\frac{L_1}{B_a(\gamma)}, q\right) \equiv \int_{\frac{L_1}{B_a(\gamma)}}^{\infty} \left[X + \frac{L_1}{B_a(\gamma)} \lambda\right] g(X; q) dX$$

and $B_a(\gamma_a) = \max\{B_0(\gamma_0), B_1(\gamma_1)\}$, where

$$\begin{aligned} B_0(\gamma_0) &\equiv 1 + \gamma_0 \lambda \\ B_1(\gamma_1) &\equiv \int_{\gamma_1}^{\infty} (Z + \gamma_1 \lambda) f(Z) dZ + \int_0^{\gamma_1} \alpha Z (1 + \lambda) f(Z) dZ \end{aligned}, \quad (13)$$

and

$$\gamma_1 \equiv e^{T-k}, \quad (14)$$

where T is defined by $h(T/\sigma_Z)/\sigma_Z = \frac{\lambda}{(1+\lambda)(1-\alpha)}$ and S is defined by $h(S/\sigma_X)/\sigma_X = \frac{\lambda}{1+\lambda}$, in which $h(\cdot)$ is a hazard rate function for a standard normal distribution.

Under fair value accounting, to balance the trade-offs in Friction 1, the social planner can tie period 2 prudential leverage L_2 to interim loan performance X , and

so precisely induce either asset substitution or no asset substitution, whichever yields the greater interim bank value at date 1. Specifically, to inhibit asset substitution, the social planner will set $L_2^{FV} = \gamma_0 X$. To induce asset substitution, instead, leverage greater than γ_0 is set. The greater period 2 leverage directly generates greater liquidity benefit, but also increases date 2 insolvency risk, jeopardizing the possibility of realizing the liquidity benefit. The balance between liquidity benefits and insolvency risk yields the optimal $L_2 = \gamma_1 X$.

The social planner also sets period 1 prudential leverage L_1 to balance the trade-offs in Friction 2. Higher leverage in period 1 directly generates greater liquidity benefit, but also increases date 1 insolvency risk, jeopardizing the possibility of realizing the liquidity benefit as such. Further, higher leverage discourages the bank from choosing high quality, while the asset substitution induced may be an indirect incentive for higher loan quality. The balance of these forces yields the optimal L_1 , which in turn induces an insolvency risk target at date 1 $G\left(\frac{L_1^{FV}}{B_a(\gamma)}\right)$.

Remark 1. Contrasts between Historical Cost Accounting and Fair Value Accounting.

(i) Under fair value accounting, the interim loan performance X is disclosed at date 1, so the period 2 prudential leverage L_2 can be tied to X , precisely inducing either asset substitution or no asset substitution as desired. That is to say, fair value accounting makes it feasible to fine-tune prudential leverage L_2 to achieve the most efficient regulation solution.

Under historical cost accounting instead, X is not reported at date 1, so the planner only sets L_2 to induce a target incidence of asset substitution, which balances the trade-offs described in Friction 1. This is relatively less efficient than that under fair value accounting.

(ii) Under historical cost accounting, the interim loan performance X is not disclosed at date 1 so there is no volatility in the interim (date 1) market value of the

bank. Hence, even at date 0, the social planner can definitely induce interim solvency with no uncertainty. To do so, period 1 prudential leverage L_1 is set so to induce the bank to choose high quality to boost date 1 bank value.

By contrast, under fair value accounting, X is reported at date 1 and the interim market value of the bank is accordingly volatile, potentially triggering interim insolvency. Because at date 0 the exact value of X to be disclosed at date 1 cannot be known, the social planner sets L_1 to induce target incidence of interim insolvency, which balances the trade-offs described in Friction 2 and 3.

(iii) As a consequence of (i) and (ii), under historical cost accounting, the social planner sets prudential leverages to induce a target incidence of asset substitution and high quality. Under fair value accounting, prudential leverages are set so as to induce the desired level of asset substitution and a target incidence of interim insolvency, which may engender either high or low quality.

In particular, given fair value accounting, it is not surprising that with certain parameter values, a combination of $\{a = 0, q = q_H\}$ that maximizes net cash flow may occur in equilibrium. More interestingly, however, with different parameter values, friction 3 above may take effect: that is, eliminating asset substitution may endanger the bank's investment in quality (i.e., a combination of $\{a = 0, q = q_L\}$), or in the other direction, tolerating asset substitution in order to increase bank's investment in quality (i.e., a combination of $\{a = 1, q = q_H\}$) may arise in equilibrium.

5 HISTORICAL COST ACCOUNTING VERSUS FAIR VALUE ACCOUNTING

Which accounting regime, historical cost or fair value, induces greater date 0 bank value π_0 ? The answer lies along the dimensions of the parameters on the asset and liability sides of bank balance sheets.

5.1 Asset Substitution Risk and Constraint

Proposition 6. *(i) Under fair value accounting, when σ_Z is increasing from 0 or when k is decreasing towards 0,*

L_2^{FV} is first decreasing ($L_2^{FV} = \gamma_0 X$) and later increasing ($L_2^{FV} = \gamma_1 X$), and L_1^{FV} is first decreasing (from $L_1^{FV} = \bar{L}_1(\gamma_0)$ to $L_1^{FV} = e^{q_L+S} B_0(\gamma_0)$) and later increasing (from $L_1^{FV} = e^{q_L+S} B_1(\gamma_1)$ to $L_1^{FV} = \bar{L}_1(\gamma_1)$). Such a pattern of change induces $a = 0$ first and $a = 1$ later, and induces q_H first, followed by q_L , and eventually q_H again.

(ii) Under historical cost accounting, when σ_Z is increasing from 0 or when k is decreasing towards 0,

L_2^{HC} and L_1^{HC} are increasing, which induces $q^{HC} = q_H$ and an increasing $\text{Prob}(a^{HC} = 1)$.

(iii) Historical cost accounting dominates fair value accounting for medium values of σ_Z and k ; Fair value accounting dominates historical cost accounting for extremely high or low values of σ_Z and k .

Greater asset substitution risk σ_Z or a looser asset substitution constraint k motivates the bank's asset substitution incentive. Therefore, what follows discusses the intuition of Proposition 6 in terms of σ_Z , on the understanding that the same intuition applies for k . The frictions introduced above feature strongly in Proposition 6.

Under *fair value accounting*, when asset substitution risk σ_Z is extremely low,

asset substitution is not so attractive to the bank in the first place. Therefore, the social planner can comfortably set high prudential leverage L_2^{FV} to prevent asset substitution without ever compromising the liquidity benefit to depositors. The high leverage in period 2 impeding asset substitution boosts the interim value of the bank, allowing ample room for the social planner to set a high leverage L_1^{FV} to induce high loans quality and boost liquidity benefits as well.

When asset substitution risk σ_Z is increasing, the bank's asset substitution incentive is strengthening. Therefore, to curb this increasing incentive, the social planner lowers the period 2 prudential leverage L_2^{FV} . However, because of the trade-off described in Friction 3, a dampened asset substitution incentive discourages investment in quality. To restore high quality, the social planner lowers the period 1 prudential leverage L_1^{FV} to reduce debt overhang. This induces no asset substitution and high quality, but at the expense of lower liquidity benefit implied by lower prudential leverage. The date 0 value of the bank decreases.

When asset substitution risk σ_Z increases further, the disincentive to quality alluded to above becomes even stronger. Further decreasing leverage L_1^{FV} to induce high quality becomes too costly, so the social planner must tolerate low quality, which leads to higher interim (date 1) insolvency risk. To curb this heightened risk, the social planner lowers the period 1 prudential leverage L_1 further. The low quality q_L in conjunction with low leverage further decreases the bank value at date 0.

When asset substitution risk σ_Z increases even more, lowering L_2 further would sacrifice too much liquidity benefit. Therefore, the social planner raises L_2 to impede asset substitution. At the same time, higher L_2 implies greater liquidity benefits and thus greater interim (date 1) bank value. Greater bank value at date 1 reduces interim insolvency risk and thus allows ample room for the social planner to increase the period 1 prudential leverage L_1 and thus enhance the period 1 liquidity benefit. For these reasons, bank value at date 0 reverses its downward slip and starts to

increase.

When asset substitution risk σ_Z continues to increase further still, Friction 3 works to its fullest extent. An ever-increasing period 2 asset substitution incentive eventually induces the bank to choose high quality in period 1, again giving the social planner ample room to increase the period 1 prudential leverage L_1 and thus enhance the period 1 liquidity benefit. Date 0 bank value increases even more.

Under *historical cost accounting*, because the interim loan performance X is not disclosed, the social planner cannot eliminate asset substitution for certain because period 2 prudential leverage L_2 cannot be fine-tuned to X . In other words, the social planner has to allow for some probability of asset substitution. Therefore, the higher the value of σ_Z , the greater the incentive for asset substitution, hence a high incidence of asset substitution. To induce an optimal incidence of asset substitution, the higher level of L_2^{HC} will be set by the social planner. At the same time, a higher level of L_2 implies greater liquidity benefit, thus higher interim (date 1) bank value. Greater date 1 bank value reduces interim insolvency risk and thus gives the social planner ample room to increase the period 1 prudential leverage L_1 to enhance the period 1 liquidity benefit. Date 0 bank value increases.

Which accounting regime, historical cost or fair value, induces a higher bank value at date 0?

Proposition 6(iii) provides the answer: Historical cost accounting dominates for mid-range values of asset substitution risk and constraint, and fair value accounting dominates for extremely high or low values. The intuition hence hinges crucially on Frictions 1, 2, and 3 and the fact that the prudential leverages L_1 and L_2 are optimally coordinated by the social planner.

When asset substitution risk σ_Z is extremely low, curbing asset substitution by setting high leverage L_2 results in higher interim bank value and lower interim insolvency risk under fair value accounting than under historical cost accounting; the

social planner can exploit this to raise L_1 and thus enhance liquidity benefits. So the date 0 bank value under fair value accounting is higher than under historical cost accounting.

By the same token, when asset substitution risk σ_Z is extremely high, tolerating asset substitution by setting high leverage L_2 results in greater interim bank value and lower interim insolvency risk under fair value accounting than under historical cost accounting. The social planner can exploit this to increase L_1 to enhance liquidity benefit. Therefore, the date 0 bank value under fair value accounting is again higher than under historical cost accounting.

For mid-range values of σ_Z , matters are dramatically different. Hence, under fair value accounting, because of the trade-off between asset substitution and quality described in Friction 3, low quality is chosen in equilibrium, which works against the relative desirability of fair value accounting, in that under historical cost accounting the high quality is always chosen in equilibrium. Because the social planner tolerates low quality in exchange for no asset substitution, a lower level of L_2 is set than under historical cost accounting, yielding a smaller liquidity benefit for period 2 debtholders. Because the two prudential leverages are coordinated, L_1 also is lower under fair value accounting. And there is an added benefit of historical cost accounting: Because of the absence of insolvency risk at date 1, so that high quality is chosen in equilibrium, the social planner can further raise the period 1 leverage L_1 to further enhance liquidity benefits. Therefore, date 0 bank value is higher under historical cost accounting than under fair value accounting.

σ_Z captures the attractiveness or risk of asset substitution. I conjecture that σ_Z differs between bank assets of different risk classes. For example, the bank has more opportunity for asset substitution (constructing derivatives for speculation) for high risk assets. In addition, I conjecture that σ_Z differs for different business cycle phases. For example, the opportunity for asset substitution in a trough is relatively low and

high at peak. Similarly, one can conjecture that k , asset substitution constraint differs for banks with differing qualities of corporate governance, or under different tightness of stress test. Proposition 6 then has the following important policy implications.

(1) It may be socially beneficial to impose prudential leverages contingent on the risk classes (σ_Z) of bank assets and the strength (k) of bank's corporate governance. Proposition 6 implies that the social planner may require *historical cost accounting for bank assets subject to medium asset substitution risk and/or for banks with medium strength of corporate governance*; fair value accounting is preferable however for the least and the most risky bank assets and/or for banks with very weak or very strong corporate governance.

(2) It may be socially beneficial to make the choice of accounting methods contingent on the phase of the business cycle. At troughs or peaks when asset substitution risk is least or greatest, fair value accounting is called for; But *during the expansion or contraction phases of business cycle, historical cost accounting* is preferable.

(3) Prudential regulations are contingent on the particular bank accounting method in place. For medium values of asset substitution risk σ_Z and corporate governance strength k , the social planner should set higher prudential leverages under the historical cost regime than under the fair value regime. However, for extremely low values of σ_Z and high values of k , the social planner should set higher prudential leverages under fair value regime. And for extremely high values of σ_Z and low values of k , even though prudential regulations should set high leverages in both times, it should be higher under fair value regime than under historical cost regime. In this regard, fair value accounting may result in both counter-cyclical and pro-cyclical prudential regulation, while historical cost accounting may result in pro-cyclical prudential regulation.

5.2 Asset Specificity

Proposition 7. (i) Under fair value accounting, when α is increasing from 0, that is, $1 - \alpha$ is decreasing from 1, then

L_2^{FV} is first constant ($L_2^{FV} = \gamma_0 X$) and later increasing ($L_2^{FV} = \gamma_1 X$), and L_1^{FV} is first constant ($L_1^{FV} = e^{q_L + S} B_0(\gamma_0)$) and later increasing (from $L_1^{FV} = e^{q_L + S} B_1(\gamma_1)$ to $L_1^{FV} = \bar{L}_1(\gamma_1)$). This pattern of change induces $a = 0$ first and $a = 1$ later, and induces q_L first and q_H later.

(ii) Under historical cost accounting, when $1 - \alpha$ is decreasing from 1, then

L_2^{HC} and L_1^{HC} are increasing, which induces $q^{HC} = q_H$ and increasing $\text{Prob}(a^{HC} = 1)$.

(iii) Historical cost accounting dominates fair value accounting for low values of $1 - \alpha$; fair value accounting dominates historical cost accounting for high values of $1 - \alpha$.

Because the liquidation value of loans at the terminal date (date 2) is αV where $\alpha \in (0, 1)$, $1 - \alpha$ represents the deadweight loss per dollar of terminal cash flow caused by liquidation due to factors such as asset specificity.

When assets are not specific, deadweight loss is low ($1 - \alpha$ is low), and asset specificity is not a big issue. In this case fair value accounting is inferior to historical cost accounting for two reasons. First, as the deadweight loss due to liquidation is small, fine-tuning period 2 prudential leverage L_2 to the interim performance report X does not generate much benefit. Second, however, fair value accounting triggers interim insolvency risk at date 1, which hurts the chances of receiving the date 2 value. This damage increases along with liquidation value (that is, when α is higher), while under historical cost accounting, as information is not updated at date 1, interim insolvency risk can be avoided. Both the benefits of fine-tuning leverage and of avoiding interim insolvency risk enhance bank value. Therefore, the social planner

will trade off between these two aspects for assets with different asset specificity.

I conjecture that generic assets are normally less liquid at cyclical troughs or contractions. Therefore, proposition 7 carries the following important policy implications.

(1) It may be socially beneficial to impose prudential leverages contingent on the specificity $(1 - \alpha)$ of bank assets. That is, social planners may require fair value accounting for specific assets whose values are low in the secondary markets; But *historical cost accounting is preferable for generic assets* whose values are relatively high in the secondary markets.

(2) It may be socially beneficial to make accounting methods contingent on the phase of the business cycle. That is, at the trough or during a contraction characterized by relatively illiquid markets, fair value accounting is called for; But at *the peak or during the expansion*, *historical cost accounting* is better.

These two implications contrast with Plantin, Sapra, and Shin (2008), who reach the opposite conclusion in a different setting in which banks make “sell versus hold” decisions in Keynesian beauty contests.

5.3 Fundamental Risk

Proposition 8. *Historical cost accounting dominates fair value accounting for lower values of σ_X ; fair value accounting dominates historical cost accounting for higher values of σ_X .*

When the fundamental risk does not exist ($\sigma_X = 0$), i.e., when the interim loan performance X is known even at date 0, there is no difference between the two accounting regimes as both regimes report the same information at date 1. When σ_X is sufficiently large, however, disclosure of the interim loan performance under fair value accounting exposes the fundamental risk at date 1, which historical cost

accounting does not permit. This is exactly the reason cited by fair value proponents. In my model, the conventional wisdom that disclosure is beneficial holds when the volatility of fundamental performance is a significant concern, because fine-tuning leverage to very volatile fundamental performance in this case is more valuable to enhance bank value. When fundamental performance is less volatile, disclosure of risk and thus fine-tuning leverage to not volatile fundamental performance does not generate too much benefit, while fair value accounting can engenders volatility in bank value and thus trigger interim insolvency, which historical cost accounting may avoid. Therefore, depending on the conditions, the social planner will trade off these two aspects in order to design the optimal regulations.

5.4 Quality Level and Quality Cost

Proposition 9. *(i) Under fair value accounting, when q_H is increasing from q_L or when c is decreasing towards 0,*

L_2^{FV} and L_1^{FV} are increasing, which induces q_L first and q_H later.

(ii) Under historical cost accounting, when q_H is increasing from q_L or when c is decreasing towards 0,

L_2^{HC} and L_1^{HC} are increasing, which induces $q^{HC} = q_H$ and increasing $\text{Prob}(a^{HC} = 1)$.

(iii) Historical cost accounting dominates fair value accounting for high values of q_H or low values of c ; fair value accounting dominates historical cost accounting for low values of q_H or high values of c .

Higher quality level q_H , which approximately captures the marginal benefits of high quality or lower marginal cost c of investment in quality motivates banks' high quality incentives. Therefore, the following focuses on the intuition of Proposition 9

in terms of q_H , with the understanding that the same intuition applies for c .

When q_H is increasing from q_L , the date 0 bank value naturally increases under both accounting regimes. For high values of q_H , the interim bank value will be high, and interim (date 1) insolvency entails a substantial social loss. In this case, historical cost accounting dominates because it avoids the interim insolvency. However, this benefit is small when the value of q_H is low, in which case fair value accounting can fine-tune period 2 prudential leverage to the interim loan performance, enhancing bank value. This constitutes the advantage of fair value accounting.

I conjecture that the marginal benefit of high quality for heterogeneous loans is greater than for homogeneous loans; The marginal cost for special types of loans is higher than commonplace loans, and quality level is relatively higher in good times than in bad times. Therefore, Proposition 9 yields the following policy implications.

(1) It may be socially beneficial to mandate accounting regimes based on the characteristics of bank loan applications. For loan applications of heterogeneous qualities (high q_H relative to q_L), historical cost accounting is called for. For those of homogeneous quality (low q_H relative to q_L), fair value accounting is preferable. In addition, for commonplace loan applications (low screening cost c), historical cost accounting is called for, but for special types (high value of c), fair value accounting is better.

(2) It may be socially beneficial to make the accounting method contingent on the phase of the business cycle. To the extent that high quality and/or low marginal cost of quality is featured in good times, and the converse is in bad times, Proposition 9 implies historical cost accounting in good times and fair value accounting in bad times. This is exactly what *impairment accounting* prescribes. Göx and Wagenhofer (2009) explain why impairment accounting may benefit borrowers. Adding to this literature, I explain why impairment accounting may also benefit lenders (banks).

5.5 Liquidity Benefit

Proposition 10. *(i) Under fair value accounting, when λ is increasing from 0, the patterns of changes in L_2^{FV} , L_1^{FV} , a^{FV} , q^{FV} , and π_0^{FV} are the same as described in Proposition 6 for an increasing value of σ_Z .*

In particular, L_2^{FV} and L_1^{FV} are increasing in λ .

(ii) Under historical cost accounting, when λ is increasing,

L_2^{HC} and L_1^{HC} are increasing, which induces $q^{HC} = q_H$ and increasing $\text{Prob}(a^{HC} = 1)$.

(iii) Historical cost accounting dominates fair value accounting for high values of λ ; fair value accounting dominates historical cost accounting for low values of λ .

The date 0 bank value π_0 has two components: the net present value of loan cash flows determined by the bank's quality q and asset substitution choice a , and the liquidity benefit to depositors determined by leverages L_2 and L_1 .

When the liquidity benefit λ is increasing, the social planner has stronger incentive to increase leverage so as to enhance liquidity benefits. Therefore, the social planner naturally increases prudential leverages L_2 and L_1 under both accounting regimes. For low values of λ , the liquidity benefit is relatively smaller, so the social planner focuses more on enhancing the net present value of loan cash flow, in which case fair value accounting is more attractive because the social planner can tie period 2 leverage to the interim performance report X , thus managing the bank's asset substitution decision more efficiently to enhance net present value of loan cash flow. For high values of λ , the liquidity benefit is greater so the social planner focuses more on enhancing liquidity benefit, making historical cost accounting more attractive in that it avoids interim insolvency risk and so safeguards deposits and liquidity benefit. Therefore, for different values of λ , the social planner will trade off these two aspects.

I conjecture that liquidity benefit is more significant in developing countries than in

developed countries, and are valued differently in different cyclical phases. Proposition 10 accordingly carries the following important policy implications.

(1) To the extent that liquidity benefits are more significant in developing countries than in developed countries, social planners may require *historical cost accounting for developing countries*. The International Financial Reporting Standards impose fair value accounting, and more and more developing countries are in fact accepting those standards. My result warns against blindly accepting fair value accounting for banks in developing countries without a consideration of the liquidity benefit to their domestic depositors.

(2) It may be socially beneficial to switch accounting methods contingent on the phase of the business cycle. To the extent that liquidity benefit is highly valued in difficult times, Proposition 10 implies that, at the peak or during expansion phase, fair value accounting is called for; however, *in the trough or during contraction phase*, *historical cost accounting* is preferable.

6 CONCLUSIONS

This study focuses on the interaction between the bank's decisions (asset substitution and quality of the loan portfolio) and the regulatory coordination (prudential regulation and bank accounting). I identify several key parameters related to bank assets and bank liabilities and investigate their effects on bank and regulatory decisions, and ultimately, on bank value. By incorporating both the asset and liability side of bank's balance sheet, the model identifies the conditions under which historical cost accounting dominates fair value accounting, and the conditions for optimal prudential regulation as described in the propositions.

The paper contributes to public policy-making in several ways. For example, prudential regulation could be cycle-contingent. Fair value accounting is optimal for peaks or troughs, historical cost accounting optimal for contraction or expansion phases. In addition, the best accounting method may vary with the economic circumstances. That is, historical cost accounting is better for good times and fair value accounting is for bad times. Geographically, the model suggests that historical cost accounting is preferable for developing countries and fair value accounting is preferable for developed countries.

My paper also contributes to banking theory. It explores the coordination of prudential regulation with bank accounting in full accounting regimes, focusing on the bank's decision on loan quality and asset substitution, while other papers study different decisions. I introduce many parameters to capture the characteristics of bank loans and deposits, which should facilitate empirical testing of my theoretical results.

The paper contrasts a pure fair value accounting regime with a pure historical cost accounting regime. In practice, however, mixed-attributes accounting regimes are applied. For example, impairment accounting combines some features of pure historical cost accounting with some features of pure fair value accounting. That is,

the two pure regimes can serve as benchmarks for future extension of the model to mixed-attributes accounting regimes. This model takes the volume of bank lending as given. Future research could endogenize lending decision to study how prudential regulation of risk-based capital ratios under BASEL III should be designed in order to maximize social value.

APPENDIX

PROOF OF PROPOSITION 1

If the bank chooses $a = 1$, it will be solvent at date 2 if and only if $V \geq L_2 \Leftrightarrow Z = e^{\sigma_Z \eta - k} \geq \frac{L_2}{X}$, and the bank's expected date 2 payoff in (1) will be $X \int_{\frac{L_2}{X}}^{\infty} (Z - \frac{L_2}{X}) f(Z) dZ$. This payoff equals $X e^{\frac{1}{2} \sigma_Z^2 - k} < 1$ at $\frac{L_2}{X} = 0$ and approaches 0 when $\frac{L_2}{X}$ approaches ∞ . Further, its derivative with respect to $\frac{L_2}{X}$ is $-X [1 - F(\frac{L_2}{X})]$.

If the bank chooses $a = 0$, it will be solvent at date 2 if and only if $V \geq L_2 \Leftrightarrow 1 \geq \frac{L_2}{X}$, and the bank's expected date 2 payoff in (1) will be $X (1 - \frac{L_2}{X})$ if $\frac{L_2}{X} \leq 1$ and 0 otherwise. Its payoff given solvency equals X at $\frac{L_2}{X} = 0$ and 0 when $\frac{L_2}{X} = 1$. Its derivative with respect to $\frac{L_2}{X}$ is $-X$.

Therefore, the bank's expected date 2 payoff given $a = 1$ and that given $a = 0$ intersect at $\frac{L_2}{X} = \gamma_0$, where γ_0 is defined by $1 - \gamma_0 = \int_{\gamma_0}^{\infty} (Z - \gamma_0) f(Z) dZ$. And the bank will choose asset substitution ($a = 1$) over no asset substitution if and only if the leverage is high enough ($L_2 > \gamma_0 X$).

By (3), if X were known to the capital market, the bank's market value of equity at date 1 given $a = 0$ is $X (1 - \frac{L_2}{X})$ and its market value of debt at date 1 given $a = 0$ is $X \frac{L_2}{X} (1 + \lambda)$, which sum to $X B_0(\frac{L_2}{X})$, where $B_0(\frac{L_2}{X}) \equiv 1 + \frac{L_2}{X} \lambda$.

Similarly, by (3), if X were known to the capital market, the bank's market value of equity at date 1 given $a = 1$ is $X \int_{\frac{L_2}{X}}^{\infty} (Z - \frac{L_2}{X}) f(Z) dZ$ and the bank's market value of debt at date 1 given $a = 1$ is $X \left[\int_{\frac{L_2}{X}}^{\infty} \frac{L_2}{X} (1 + \lambda) f(Z) dZ + \int_0^{\frac{L_2}{X}} \alpha Z (1 + \lambda) f(Z) dZ \right]$, which sum up to $X B_1(\frac{L_2}{X})$, where

$$B_1\left(\frac{L_2}{X}\right) \equiv \int_{\frac{L_2}{X}}^{\infty} \left(Z + \frac{L_2}{X} \lambda\right) f(Z) dZ + \int_0^{\frac{L_2}{X}} \alpha Z (1 + \lambda) f(Z) dZ.$$

■

PROOF OF PROPOSITION 2

Note that $\pi_1(q, L_2)$ is increasing in q , hence $\pi_1(q_L, L_2) < \pi_1(q_H, L_2)$. Thus, there are three cases to discuss:

(i) When $L_1 \leq \pi_1(q_L, L_2)$, the bank's expected payoff in (6) is $-c + \pi_1(q_H, L_2) - L_1$ given q_H and $\pi_1(q_L, L_2) - L_1$ given q_L . Because $\pi_1(q_H, L_2) - \pi_1(q_L, L_2) > c$, the bank will choose q_H .

(ii) When $L_1 \in (\pi_1(q_L, L_2), \pi_1(q_H, L_2)]$, the bank's expected payoff in (6) is

$$-c + \pi_1(q_H, L_2) - L_1$$

given q_H and 0 given q_L , hence, the bank will choose q_H if and only if $L_1 \leq \pi_1(q_H, L_2) - c$.

(iii) When $L_1 > \pi_1(q_H, L_2)$, the bank's expected payoff in (6) is $-c$ given q_H and 0 given q_L so the bank will choose q_L .

To summarize, the bank will choose q_H if and only if $L_1 \leq \pi_1(q_H, L_2) - c$.

Define $\pi_0 \equiv D_0 + E_0$ as the ex ante bank value. When $L_1 > \pi_1(q_H, L_2) - c$, $E_0 = 0$ by (6) and $D_0 = 0$ by (7), hence $\pi_0 \equiv D_0 + E_0 = 0$. When $L_1 \leq \pi_1(q_H, L_2) - c$, $E_0 = -c + \pi_1(q_H, L_2) - L_1$ by (6) and $D_0 = L_1(1 + \lambda)$ by (7), hence $\pi_0 = -c + \pi_1(q_H, L_2) + L_1\lambda$. ■

PROOF OF PROPOSITION 3

The social planner sets $\{L_1, L_2\}$ to maximize the date 0 bank value $\pi_0 \equiv D_0 + E_0$, which is $\pi_0 = -c + \pi_1(q_H, L_2) + L_1\lambda$ when $L_1 \leq \pi_1(q_H, L_2) - c$, as stated at the end of the proof of Proposition 2. Thus, in this case, the optimal value of L_1 is $\pi_1(q_H, L_2) - c$. Therefore $\pi_0 = [\pi_1(q_H, L_2) - c](1 + \lambda)$, which is greater than 0, which is the value of π_0 when $L_1 > \pi_1(q_H, L_2) - c$. Hence, $q^{HC} = q_H$.

Therefore, the optimal value of L_2 is characterized by the first-order condition

$$\pi_0 = [\pi_1(q_H, L_2) - c](1 + \lambda)$$

with respect to L_2 , which is given in (8) in the statement of the proposition. As a consequence, $Prob(a^{HC} = 1) = G\left(\frac{L_2^{HC}}{\gamma_0}\right)$, $L_1^{HC} = \pi_1(q_H, L_2^{HC}) - c$, and $\pi^{HC} = [\pi_1(q_H, L_2^{HC}) - c](1 + \lambda)$. ■

PROOF OF PROPOSITION 4

By (9), $\frac{\partial E_0}{\partial L_1} = -B_a(\gamma)[1 - \Phi\left(\ln \frac{L_1}{B_a(\gamma)} - q\right)/\sigma_X] < 0$, which implies that the slope of E_0 given q_H is steeper than that given q_L . Moreover, at $L_1 = 0$, E_0 given q_H equals $B_a(\gamma)\mathbb{E}[X|q_H] - c$ and E_0 given q_L equals $B_a(\gamma)\mathbb{E}[X|q_L]$; The former is greater than the latter by the assumption that $\mathbb{E}[X|q_H] - \mathbb{E}[X|q_L] > c$ and by the fact that $B_a(\gamma) \geq 1$. Furthermore, when $L_1 \rightarrow \infty$, E_0 given q_H approaches $-c$ and E_0 given q_L approaches 0. Thus, E_0 given q_H exceeds E_0 given q_L if and only if $L_1 \leq \bar{L}_1$ where \bar{L}_1 is the value of L_1 where the two equity values are equal and are characterized in (11) in the statement of the proposition.

Thus, when $L \leq \bar{L}_1$, the bank will choose q_H , and by (9), its date 0 equity value will be

$$-c + \int_{\frac{L_1}{B_a(\gamma)}}^{\infty} [XB_a(\gamma) - L_1] g(X; q_H) dX$$

by (10), its date 0 debt value will be

$$D_0 = \int_{\frac{L_1}{B_a(\gamma)}}^{\infty} L_1(1 + \lambda) g(X; q_H) dX$$

and therefore the date 0 bank value is

$$\pi_0(L_1, q_H) = -c + \int_{\frac{L_1}{B_a(\gamma)}}^{\infty} [XB_a(\gamma) + L_1\lambda] g(X; q_H) dX.$$

Similarly, when $L > \bar{L}_1$, the bank will choose q_L , and by (9) its date 0 equity value will be $\int_{\frac{L_1}{B_a(\gamma)}}^{\infty} [XB_a(\gamma) - L_1] g(X; q_L) dX$ and by (10), its date 0 debt value will be

$$D_0 = \int_{\frac{L_1}{B_a(\gamma)}}^{\infty} L_1(1 + \lambda) g(X; q_L) dX$$

and therefore the date 0 bank value is

$$\pi_0(L_1, q_L) = \int_{\frac{L_1}{B_a(\gamma)}}^{\infty} [XB_a(\gamma) + L_1\lambda] g(X; q_L) dX.$$

■

PROOF OF PROPOSITION 5

Recall from the proof of Proposition 4 that when $L \leq \bar{L}_1$, the date 0 bank value is $\pi_0(L_1, q_H) = -c + B_a(\gamma)A\left(\frac{L_1}{B_a(\gamma)}, q_H\right)$ where $A\left(\frac{L_1}{B_a(\gamma)}, q\right) \equiv \int_{\frac{L_1}{B_a(\gamma)}}^{\infty} \left[X + \frac{L_1}{B_a(\gamma)}\lambda\right] g(X; q) dX$.

Because $\frac{\partial \pi_0(L_1, q_H)}{\partial B_a(\gamma)} = A - \frac{\partial A}{\partial \left(\frac{L_1}{B_a(\gamma)}\right)} \frac{L_1}{B_a(\gamma)} > 0$, the social planner will set the value of $\frac{L_2}{X} = \gamma$ to maximize $B_a(\gamma)$. By (4), $B_0\left(\frac{L_2}{X}\right)$ attains its maximum value at $\frac{L_2}{X} = \gamma_0$ and $B_1\left(\frac{L_1}{X}\right)$ attains its maximum value at $\frac{L_2}{X} = \gamma_1$ where $\gamma_1 = e^{T-k}$ where T is characterized by $h(T/\sigma_Z)/\sigma_Z = \frac{\lambda}{(1+\lambda)(1-\alpha)}$. Thus, the social planner will set $\frac{L_2}{X} = \gamma_0$ if $B_0(\gamma_0) \geq B_1(\gamma_1)$ and $\frac{L_2}{X} = \gamma_1$ if $B_1(\gamma_1) > B_0(\gamma_0)$.

In addition,

$$\begin{aligned} \frac{\partial \pi_0(L_1, q_H)}{\partial L_1} &= \frac{\partial A}{\partial \left(\frac{L_1}{B_a(\gamma)}\right)} = \\ [1 - \Phi \left(\left(\ln \frac{L_1}{B_a(\gamma)} - q \right) / \sigma_X \right)] &[\lambda - (1 + \lambda)h \left(\left(\ln \frac{L_1}{B_a(\gamma)} - q \right) / \sigma_X \right) / \sigma_X]. \end{aligned} \quad (15)$$

Note that at $\frac{L_1}{B_a(\gamma)} = 0$, $A = \mathbb{E}[X|q_H]$ and when $\frac{L_1}{B_a(\gamma)} \rightarrow \infty$, A approaches 0. Further, it reaches its maximum value at $\frac{L_1}{B_a(\gamma)} = e^{q+S}$ where S is defined by $h(S/\sigma_X)/\sigma_X = \frac{\lambda}{1+\lambda}$. Moreover, it is concave for lower values of $\frac{L_1}{B_a(\gamma)}$ and convex for higher values of $\frac{L_1}{B_a(\gamma)}$. Therefore, $A - \frac{\partial A}{\partial \left(\frac{L_1}{B_a(\gamma)}\right)} \frac{L_1}{B_a(\gamma)} > 0$.

Again from the proof of Proposition 4, when $L > \bar{L}_1$, the date 0 bank value is $\pi_0(L_1, q_L) = B_a(\gamma)A \left(\frac{L_1}{B_a(\gamma)}, q_L \right)$. A similar analysis again generates the same decision rule for L_2 .

Recall from the above that by (15), $\pi_0(L_1, q)$ attains its maximum value at $\frac{L_1}{B_a(\gamma)} = e^{q+S}$. When $\frac{\bar{L}_1}{B_a(\gamma)} > e^{q_L+S}$, however, this ideal value is not attainable for a social planner who wants to induce q_L , and so must set $L_1 = \bar{L}_1$, which violates the assumption that when bank is indifferent between q_H and q_L , it will choose q_H . Thus, it must be the case that $\frac{\bar{L}_1}{B_a(\gamma)} \leq e^{q_L+S}$, which implies the following:

(i) If the aim is to induce q_L , the social planner sets $L_1 = e^{q_L+S}B_a(\gamma)$ and thus

$$\pi_0(e^{q_L+S}, q_L) = B_a(\gamma)A(e^{q_L+S}, q_L).$$

(ii) If the aim is to induce q_H , the social planner sets $L_1 = \bar{L}_1(\gamma)$ because $L_1 = e^{q_H+S}B_a(\gamma)$ is not feasible and thus $\pi_0\left(\frac{\bar{L}_1(\gamma)}{B_a(\gamma)}, q_H\right) = -c + B_a(\gamma)A\left(\frac{\bar{L}_1(\gamma)}{B_a(\gamma)}, q_H\right)$. Overall, the above results imply that the social planner will induce q_H if and only if

$$A\left(\frac{\bar{L}_1(\gamma)}{B_a(\gamma)}, q_H\right) - A(e^{q_L+S}, q_L) \geq \frac{c}{B_a(\gamma)}.$$

■

PROOF OF PROPOSITION 6

Fair Value Accounting:

By (2), $\frac{\partial \gamma_0}{\partial \sigma_Z} < 0$. By (13), $\frac{\partial B_0(\gamma_0)}{\partial \sigma_Z} < 0$. Conversely, by (14), $\frac{\partial \gamma_1}{\partial \sigma_Z} > 0$. By (13), $\frac{\partial B_1(\gamma_1)}{\partial \sigma_Z} > 0$. Therefore, $B_0(\gamma_0) > B_1(\gamma_1)$ for lower values of σ_Z and vice versa for high values.

Then, for lower values of σ_Z , the social planner will set $L_2 = \gamma_0 X$ to induce $B_0(\gamma_0)$. In these cases, a higher value of σ_Z will lead to a lower value of $B_0(\gamma_0)$, which in turn

will lead to a lower value of $\bar{L}_1(\gamma_0)$ by (11). Furthermore, a lower value of $\bar{L}_1(\gamma_0)$ will lead to a lower value of the left-hand side of (12), which implies that it will become less beneficial for the planner to induce q_H .

By similar reasoning, for higher values of σ_Z , the social planner will set $L_2 = \gamma_1 X$ to induce $B_1(\gamma_1)$. In these cases, a higher value of σ_Z will lead to a higher value of $B_1(\gamma_1)$, which in turn will lead to a higher value of $\bar{L}_1(\gamma_1)$ by (11). Furthermore, a higher value of $\bar{L}_1(\gamma_1)$ will lead to a higher value of the left-hand side of (12), which implies that it will become more beneficial for the planner to induce q_H .

The foregoing results imply that when σ_Z is increasing from 0, L_2^{FV} is first decreasing ($L_2^{FV} = \gamma_0 X$) and later increasing ($L_2^{FV} = \gamma_1 X$). Such a pattern induces $a = 0$ first and $a = 1$ later.

By Proposition 5, when σ_Z is increasing from 0, L_1^{FV} is first decreasing (from $L_1^{FV} = \bar{L}_1(\gamma_0)$ to $L_1^{FV} = e^{q_L+S} B_0(\gamma_0)$) and later increasing (from $L_1^{FV} = e^{q_L+S} B_1(\gamma_1)$ to $L_1^{FV} = \bar{L}_1(\gamma_1)$). Such a pattern induces q_H first, later q_L , and eventually q_H later still.

By the foregoing results and by Proposition 5, when σ_Z is increasing from 0, the equilibrium date 0 bank value changes from $\pi_0^{FV} = B_0(\gamma_0) A\left(\frac{\bar{L}_1(\gamma_0)}{B_0(\gamma_0)}, q_H\right) - c$ to $\pi_0^{FV} = B_0(\gamma_0) A\left(e^{q_L+S}, q_L\right)$, then to $\pi_0^{FV} = B_1(\gamma_1) A\left(e^{q_L+S}, q_L\right)$, and eventually to $\pi_0^{FV} = B_1(\gamma_1) A\left(\frac{\bar{L}_1(\gamma_1)}{B_1(\gamma_1)}, q_H\right) - c$.

Historical Cost Accounting:

By (8), $\frac{\partial L_2^{HC}}{\partial \sigma_Z} > 0$. And because $\frac{\partial \gamma_0}{\partial \sigma_Z} < 0$, $Prob(a^{HC} = 1) = G\left(\frac{L_2^{HC}}{\gamma_0}\right)$ is increasing in σ_Z .

By (5), $\frac{\partial \pi_1(L_2^{HC}, q_H)}{\partial \sigma_Z} > 0$ and therefore $\frac{\partial L_1^{HC}}{\partial \sigma_Z} > 0$ and $\frac{\partial \pi_0^{HC}}{\partial \sigma_Z} > 0$.

Comparison of Fair Value Accounting and Historical Cost Accounting:

First show that when σ_Z is sufficiently large, $\pi_0^{FV} > \pi_0^{HC}$.

Note that $\frac{\partial \pi_0^{HC}}{\partial \sigma_Z} = \int_0^{\frac{L_2^{HC}}{\gamma_0}} X \frac{\partial B_1\left(\frac{L_2^{HC}}{X}\right)}{\partial \sigma_Z} g(X; q_H) dX$ by the expression for π_0^{HC} in Proposition 3. Note that when $\sigma_Z \rightarrow \infty$, $L_2^{HC} \rightarrow \infty$ and $\gamma_0 \rightarrow 0$, and thus

$$\frac{\partial \pi_0^{HC}}{\partial \sigma_Z} \rightarrow \int_0^\infty X \frac{\partial B_1\left(\frac{L_2^{HC}}{X}\right)}{\partial \sigma_Z} g(X; q_H) dX.$$

Next note that when σ_Z is sufficiently large, $\pi_0^{FV} = B_1(\gamma_1) A\left(\frac{\bar{L}_1(\gamma_1)}{B_1(\gamma_1)}, q_H\right) - c$ according to Proposition 5. Therefore,

$$\begin{aligned} \frac{\partial \pi_0^{FV}}{\partial \sigma_Z} &= (1 + \lambda) \left(\frac{\bar{L}_1(\gamma_1)}{B_1(\gamma_1)} \right)^2 g \left(\frac{\bar{L}_1(\gamma_1)}{B_1(\gamma_1)} \right) \frac{\partial B_1(\gamma_1)}{\partial \sigma_Z} + \int_{\frac{\bar{L}_1(\gamma_1)}{B_1(\gamma_1)}}^{\infty} X \frac{\partial B_1(\gamma_1)}{\partial \sigma_Z} g(X; q_H) dX \\ &\quad + \frac{\partial \bar{L}_1(\gamma_1)}{\partial \sigma_Z} \left[1 - G \left(\frac{\bar{L}_1(\gamma_1)}{B_1(\gamma_1)} \right) \right] \left[\lambda - (1 + \lambda) h \left(\left(\ln \frac{\bar{L}_1(\gamma_1)}{B_1(\gamma_1)} - q_H \right) / \sigma_X \right) / \sigma_X \right]. \end{aligned} \quad (16)$$

Note that when $\sigma_Z \rightarrow \infty$, $\gamma_1 \rightarrow \infty$ and $B_1(\gamma_1) \rightarrow \infty$, and thus

$$\begin{aligned} \frac{\partial \pi_0^{FV}}{\partial \sigma_Z} &\rightarrow (1 + \lambda) \left(\frac{\bar{L}_1(\gamma_1)}{B_1(\gamma_1)} \right)^2 g \left(\frac{\bar{L}_1(\gamma_1)}{B_1(\gamma_1)} \right) \frac{\partial B_1(\gamma_1)}{\partial \sigma_Z} + \int_0^{\infty} X \frac{\partial B_1(\gamma_1)}{\partial \sigma_Z} g(X; q_H) dX \\ &\quad + \frac{\partial \bar{L}_1(\gamma_1)}{\partial \sigma_Z} \left[1 - G \left(\frac{\bar{L}_1(\gamma_1)}{B_1(\gamma_1)} \right) \right] \left[\lambda - (1 + \lambda) h \left(\left(\ln \frac{\bar{L}_1(\gamma_1)}{B_1(\gamma_1)} - q_H \right) / \sigma_X \right) / \sigma_X \right]. \end{aligned} \quad (17)$$

Because the second and third terms of the preceding expression are both positive and because the first term equals $\frac{\partial \pi_0^{HC}}{\partial \sigma_Z}$ in the limit, when $\sigma_Z \rightarrow \infty$, $\frac{\partial \pi_0^{FV}}{\partial \sigma_Z} > \frac{\partial \pi_0^{HC}}{\partial \sigma_Z}$. Because when $\sigma_Z \rightarrow \infty$, both π_0^{FV} and π_0^{HC} go to ∞ and $\frac{\partial \pi_0^{FV}}{\partial \sigma_Z} > \frac{\partial \pi_0^{HC}}{\partial \sigma_Z}$, it must be the case that when σ_Z is sufficiently large, $\pi_0^{FV} > \pi_0^{HC}$.

Next show that when σ_Z is sufficiently low, $\pi_0^{FV} > \pi_0^{HC}$ where

$$\pi_0^{FV} = B_0(\gamma_0) A \left(\frac{\bar{L}_1(\gamma_0)}{B_0(\gamma_0)}, q_H \right) - c$$

according to Proposition 5.

Note that when $\sigma_Z \rightarrow 0$, $L_2^{HC} \rightarrow 0$ and $\gamma_0 \rightarrow 1$, and thus $\pi_1 \rightarrow \mathbb{E}[X|q_H]$. Thus, when $\sigma_Z \rightarrow 0$, $\pi_0^{HC} \rightarrow (1 + \lambda)\mathbb{E}[X|q_H] - (1 + \lambda)c$. Moreover, when $\sigma_Z \rightarrow 0$, $\gamma_0 \rightarrow 1$ and thus $B_0(\gamma_0) \rightarrow 1 + \lambda$, which in turn implies that $\pi_0^{FV} \rightarrow (1 + \lambda) \int_{\frac{\bar{L}_1(\gamma_0)}{1+\lambda}}^{\infty} \left[X + \frac{\bar{L}_1(\gamma_0)}{1+\lambda} \lambda \right] g(X; q_H) dX - c$. Because $\int_y^{\infty} [X + y\lambda] g(X; q_H) dX$ is increasing in y for $y < e^{q_H+S}$, it must be the case that when σ_Z is sufficiently low, $\pi_0^{FV} > \pi_0^{HC}$.

Overall, because π_0^{FV} is a U-shaped curve of σ_Z and π_0^{HC} is an increasing function of σ_Z , and because $\pi_0^{FV} > \pi_0^{HC}$ for both extremely low values and extremely high values of σ_Z , it must be the case that $\pi_0^{HC} > \pi_0^{FV}$ for medium values of σ_Z and the converse is true for extreme values of σ_Z .

The proof of the results regarding k follows the same reasoning as above and can accordingly be omitted. ■

PROOF OF PROPOSITION 7

Fair Value Accounting:

By (2), $\frac{\partial \gamma_0}{\partial \alpha} = 0$. By (13), $\frac{\partial B_0(\gamma_0)}{\partial \alpha} = 0$. In contrast, by (14), $\frac{\partial \gamma_1}{\partial \alpha} > 0$. By (13), $\frac{\partial B_1(\gamma_1)}{\partial \alpha} > 0$. Therefore, $B_0(\gamma_0) > B_1(\gamma_1)$ for lower values of α and vice versa.

Hence, for lower values of α , the social planner will set $L_2 = \gamma_0 X$ to induce $B_0(\gamma_0)$,

and for higher values of σ_Z will set $L_2 = \gamma_1 X$ to induce $B_1(\gamma_1)$. In the latter case, a higher value of α will lead to a higher value of $B_1(\gamma_1)$, which in turn will lead to a higher value of $\bar{L}_1(\gamma_1)$ by (11). Furthermore, a higher value of $\bar{L}_1(\gamma_1)$ will lead to a higher value of the left-hand side of (12), which implies that it will become more beneficial for the planner to induce q_H .

The foregoing results imply that when α is increasing from 0, L_2^{FV} is constant first ($L_2^{FV} = \gamma_0 X$) and increasing later ($L_2^{FV} = \gamma_1 X$). Such a pattern induces $a = 0$ first and $a = 1$ later.

By Proposition 5, when α is increasing from 0, L_1^{FV} is constant first ($L_1^{FV} = e^{q_L+S} B_0(\gamma_0)$) and increasing later (from $L_1^{FV} = e^{q_L+S} B_1(\gamma_1)$ to $L_1^{FV} = \bar{L}_1(\gamma_1)$). Such a pattern induces q_L first and q_H later.

By the foregoing results and by Proposition 5, when α is increasing from 0, the equilibrium date 0 bank value changes from $\pi_0^{FV} = B_0(\gamma_0)A(e^{q_L+S}, q_L)$ to $\pi_0^{FV} = B_1(\gamma_1)A(e^{q_L+S}, q_L)$, and eventually to $\pi_0^{FV} = B_1(\gamma_1)A\left(\frac{\bar{L}_1(\gamma_1)}{B_1(\gamma_1)}, q_H\right) - c$.

Historical Cost Accounting:

By (8), $\frac{\partial L_2^{HC}}{\partial \alpha} > 0$ and therefore $Prob(a^{HC} = 1) = G\left(\frac{L_2^{HC}}{\gamma_0}\right)$ is increasing in α .

By (5), $\frac{\partial \pi_1(L_2^{HC}, q_H)}{\partial \alpha} > 0$ and therefore $\frac{\partial L_1^{HC}}{\partial \alpha} > 0$ and $\frac{\partial \pi_0^{HC}}{\partial \alpha} > 0$.

Comparison of Fair Value Accounting and Historical Cost Accounting:

First show that when α is sufficiently large, $\pi_0^{HC} > \pi_0^{FV}$.

Note that when $\alpha = 1$, $B'_1\left(\frac{L_2^{HC}}{X}\right) > 0$ and thus $L_2^{HC} \rightarrow \infty$, which implies that $B_1\left(\frac{L_2^{HC}}{X}\right) = \mathbb{E}[Z](1+\lambda)$ and $\pi_1 = \mathbb{E}[X|q_H]\mathbb{E}[Z](1+\lambda)$. Thus, $\pi_0^{HC} = \mathbb{E}[X|q_H]\mathbb{E}[Z](1+\lambda)^2 - c(1+\lambda)$.

Next note that when $\alpha = 1$, $\pi_0^{FV} = B_1(\gamma_1)A\left(\frac{\bar{L}_1(\gamma_1)}{B_1(\gamma_1)}, q_H\right) - c$ according to Proposition 5. Because $\gamma_1 \rightarrow \infty$ and $B_1(\gamma_1) \rightarrow \mathbb{E}[Z](1+\lambda)$ when $\alpha = 1$,

$$\pi_0^{FV} \rightarrow \int_{\frac{\bar{L}_1(\gamma_0)}{\mathbb{E}[Z](1+\lambda)}}^{\infty} [X\mathbb{E}[Z](1+\lambda) + \bar{L}_1(\gamma_1)\lambda] g(X; q_H) dX - c.$$

By (11), $\pi_0^{HC} > \pi_0^{FV}$ if and only if

$$\mathbb{E}[X|q_H]\mathbb{E}[Z](1+\lambda)^2 > \int_{\frac{\bar{L}_1(\gamma_0)}{\mathbb{E}[Z](1+\lambda)}}^{\infty} X\mathbb{E}[Z](1+\lambda)^2 g(X; q_H) dX - \lambda\mathbb{E}[Z](1+\lambda) \int_{\frac{\bar{L}_1(\gamma_0)}{\mathbb{E}[Z](1+\lambda)}}^{\infty} \left[X - \frac{\bar{L}_1(\gamma_0)}{\mathbb{E}[Z](1+\lambda)}\right] g(X; q_L) dX,$$

which always holds.

Similar reasoning demonstrates that when α is sufficiently low, $\pi_0^{FV} > \pi_0^{HC}$ due to (i) $B_0(\gamma_0) > B_1(\gamma_1)$ and (ii) c is sufficiently high.

Overall, both π_0^{FV} and π_0^{HC} are increasing functions of α and in particular π_0^{HC} is linear in α . In addition, because $\pi_0^{FV} > \pi_0^{HC}$ when $\alpha = 0$ and $\pi_0^{HC} > \pi_0^{FV}$ when $\alpha = 1$, it must be the case that $\pi_0^{HC} > \pi_0^{FV}$ for large values of α and vice versa. ■

PROOF OF PROPOSITION 8

Fair Value Accounting:

By Proposition 5, it is straightforward to show that $\pi_0^{FV} = B_a(\gamma_a)A(e^{q_L+S}, q_L)$ or $\pi_0^{FV} = B_a(\gamma_a)A\left(\frac{\bar{L}_1(\gamma_a)}{B_a(\gamma_a)}, q_H\right) - c$ is increasing in σ_X .

Historical Cost Accounting:

For log normal distributions, density is decreasing in σ_X for $X \in (e^{q-\sigma_X}, e^{q+\sigma_X})$ and increasing in σ_X otherwise. Therefore, $\frac{\partial \pi_1(L_2^{HC}, q_H)}{\partial \sigma_X} > 0$ for lower values of σ_X and $\frac{\partial \pi_1(L_2^{HC}, q_H)}{\partial \sigma_X} < 0$ for higher values of σ_X . Thus, π_0^{HC} follows the same pattern.

Comparison of Fair Value Accounting and Historical Cost Accounting:

At $\sigma_X = 0$, $\pi_0^{HC} = \pi_0^{FV}$. Because π_0^{FV} is increasing in σ_X and π_0^{HC} is increasing for lower values of σ_X and decreasing for higher values of σ_X , $\pi_0^{HC} > \pi_0^{FV}$ for lower values of σ_X and vice versa. ■

PROOF OF PROPOSITION 9

Fair Value Accounting:

A higher value of q_H will lead to a higher value of the left-hand side of (12), which implies that it will become more beneficial for the planner to induce q_H .

By Proposition 5, when q_H is increasing from q_L , L_1^{FV} is constant first ($L_1^{FV} = e^{q_L+S}B_a(\gamma_a)$) and increasing later ($L_1^{FV} = \bar{L}_1(\gamma_a)$). Such a pattern induces q_L first and q_H later.

By the foregoing results and by Proposition 5, when q_H is increasing from q_L , the equilibrium date 0 bank value is constant first ($\pi_0^{FV} = B_a(\gamma_a)A(e^{q_L+S}, q_L)$) and increasing later ($\pi_0^{FV} = B_a(\gamma_a)A\left(\frac{\bar{L}_1(\gamma_a)}{B_a(\gamma_a)}, q_H\right) - c$).

Historical Cost Accounting:

By (8), $\frac{\partial L_2^{HC}}{\partial q_H} > 0$ and therefore $Prob(a^{HC} = 1) = G\left(\frac{L_2^{HC}}{\gamma_0}\right)$ is increasing in q_H .

By (5), $\frac{\partial \pi_1(L_2^{HC}, q_H)}{\partial q_H} > 0$ and therefore $\frac{\partial L_1^{HC}}{\partial q_H} > 0$ and $\frac{\partial \pi_0^{HC}}{\partial q_H} > 0$.

Comparison of Fair Value Accounting and Historical Cost Accounting:

First show that when q_H is sufficiently large, $\pi_0^{HC} > \pi_0^{FV}$ where

$$\pi_0^{FV} = B_1(\gamma_1)A\left(\frac{\bar{L}_1(\gamma_1)}{B_1(\gamma_1)}, q_H\right) - c$$

according to Proposition 5.

By (11), $\pi_0^{HC} > \pi_0^{FV}$ if and only if

$$\begin{aligned} & \int_{\frac{L_2}{\gamma_0}}^{\infty} X B_0\left(\frac{L_2}{X}\right) (1 + \lambda) g(X; q_H) dX + \int_0^{\frac{L_2}{\gamma_0}} X B_1\left(\frac{L_2}{X}\right) (1 + \lambda) g(X; q_H) dX > \\ & \int_{\frac{\bar{L}_1(\gamma_1)}{B_1(\gamma_1)}}^{\infty} X B_1(\gamma_1) (1 + \lambda) g(X; q_H) dX - \lambda B_1(\gamma_1) \int_{\frac{\bar{L}_1(\gamma_1)}{B_1(\gamma_1)}}^{\infty} \left[X - \frac{\bar{L}_1(\gamma_1)}{B_1(\gamma_1)} \right] g(X; q_L) dX. \end{aligned} \quad (18)$$

The preceding inequality holds for sufficiently large values of q_H , because as $q_H \rightarrow \infty$, $L_2^{HC} \rightarrow \infty$ and $\bar{L}_1(\gamma_a) \rightarrow \infty$.

Similar reasoning demonstrates that when $q_H = q_L$, $\pi_0^{FV} > \pi_0^{HC}$.

Thus, it must be the case that $\pi_0^{HC} > \pi_0^{FV}$ for large values of q_H and vice versa.

The proof of the results regarding c follows the same reasoning and can accordingly be omitted. ■

PROOF OF PROPOSITION 10

Fair Value Accounting:

By (13), $B_0(\gamma_0) = 1$ at $\lambda = 0$ and is linearly increasing in λ . By (13), $B_1(\gamma_1) = \mathbb{E}[Z] < 1$ at $\lambda = 0$ and is increasing and convex in λ . Therefore, $B_0(\gamma_0) > B_1(\gamma_1)$ for lower values of λ and vice versa.

Thus, for lower values of λ , the social planner will set $L_2 = \gamma_0 X$ to induce $B_0(\gamma_0)$, and for higher values of λ will set $L_2 = \gamma_1 X$ to induce $B_1(\gamma_1)$. In the latter case, a higher value of λ will lead to a lower value of the left-hand side of (12), which implies that it will become less beneficial for the planner to induce q_H .

The foregoing results imply that when λ is increasing from 0, the patterns of changes in L_2^{FV} , L_1^{FV} , a^{FV} , q^{FV} , and π_0^{FV} follow trend described in Proposition 6 for an increasing value of σ_Z .

Historical Cost Accounting:

By (8), $\frac{\partial L_2^{HC}}{\partial \lambda} > 0$ and therefore $\text{Prob}(a^{HC} = 1) = G\left(\frac{L_2^{HC}}{\gamma_0}\right)$ is increasing in λ .

By (5), $\frac{\partial \pi_1(L_2^{HC}, q_H)}{\partial \lambda} > 0$ and therefore $\frac{\partial L_1^{HC}}{\partial \lambda} > 0$ and $\frac{\partial \pi_0^{HC}}{\partial \lambda} > 0$.

Comparison of Fair Value Accounting and Historical Cost Accounting:

First show that when λ is sufficiently large, $\pi_0^{HC} > \pi_0^{FV}$, where

$$\pi_0^{FV} = B_1(\gamma_1) A\left(\frac{\bar{L}_1(\gamma_1)}{B_1(\gamma_1)}, q_H\right) - c$$

according to Proposition 5.

By (11), $\pi_0^{HC} > \pi_0^{FV}$ if and only if

$$\begin{aligned} & \int_{\frac{L_2}{\gamma_0}}^{\infty} X B_0\left(\frac{L_2}{X}\right) (1 + \lambda) g(X; q_H) dX + \int_0^{\frac{L_2}{\gamma_0}} X B_1\left(\frac{L_2}{X}\right) (1 + \lambda) g(X; q_H) dX > \\ & \int_{\frac{\bar{L}_1(\gamma_1)}{B_1(\gamma_1)}}^{\infty} X B_1(\gamma_1) (1 + \lambda) g(X; q_H) dX - \lambda B_1(\gamma_1) \int_{\frac{\bar{L}_1(\gamma_1)}{B_1(\gamma_1)}}^{\infty} \left[X - \frac{\bar{L}_1(\gamma_1)}{B_1(\gamma_1)} \right] g(X; q_L) dX, \end{aligned} \quad (19)$$

which holds for sufficiently large values of λ .

Similar reasoning demonstrates that when $\lambda = 0$,

$$\pi_0^{FV} = \pi_0^{HC} = \mathbb{E}[X|q_H] - c$$

and $\frac{\partial \pi_0^{FV}}{\partial \lambda} > \frac{\partial \pi_0^{HC}}{\partial \lambda}$ because q_H is sufficiently high.

Overall, both π_0^{FV} and π_0^{HC} are increasing functions of λ . Moreover, when $\lambda = 0$, $\pi_0^{FV} = \pi_0^{HC}$ and $\frac{\partial \pi_0^{FV}}{\partial \lambda} > \frac{\partial \pi_0^{HC}}{\partial \lambda}$. Furthermore, when λ is sufficiently large, $\pi_0^{HC} > \pi_0^{FV}$. Thus, it must be the case that $\pi_0^{HC} > \pi_0^{FV}$ for large values of λ and vice versa. ■

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